Post-seismic Deformation in the Vrancea Region, Romania

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The Vrancea region in Romania is known for its very complicated tectonic setting. It is the border region of three main tectonic units in southeast Romania. The collision between these units is believed to be the origin of the East and South Carpathians. The Vrancea region is also the home of a large amount of intermediate-depth earthquakes that are all confined to a relatively small volume corresponding with a seismic detectable slab starting at a depth of 60-70 km. What this slab exactly is, is still is a point of discussion among scientists. One the outstanding questions is whether the slab is still attached, in progress of detachment or already detached.

GPS campaigns of three-dimensional crustal displacements in this region, observing the combined *Netherlands Research Center for Integrated Solid Earth Sciences* (ISES), *German Research Foundation* (DFG) and *Collaborative Research Center* (CRC 461) networks in Romania, are expected to assist in solving these issues. The measurements were initiated in 1995 by the *Central European Regional Geodynamics Project* (CERGOP) using eight sites and were further extended and densified around the Vrancea region by CRC 461 in 1997 to include 18 sites and eight additional sites in 2000. Further network expansions by ISES in 2002 and 2003 yielded a current total of 56 stations covering an area of around 450 x 550 km from the Apuseni Mountains to the Black-Sea coast. The network was (partly) measured during 13 GPS campaigns. Data processing was performed using NASA Jet Propulsion Laboratory's (JPL) GIPSY Precise Point Positioning strategy and GPS motions were computed in the ITRF-2000 reference frame. This results in GPS vectors relative to the assumed stable Eurasian Platform. Only stations that have been measured during at least four campaigns (only points older than 1998) and showing a sufficient confidence level, have been used for interpretation.

It might be possible that ongoing deformation related to large earthquakes that have hit the Vrancea region in the past could have a considerable contribution to GPS-observed displacements rates. This so-called post-seismic deformation results from viscoelastic relaxation of the Earth due to the redistributed stress and strain after faulting.
The earthquakes used in the simulations are the March 4 1977, the August 30 1986 and the May 30 1990 earthquakes. These are, according to the Harvard CMT catalogue and regional solutions, the only earthquakes in Romania of the last 30 years with a moment magnitude of about 7 or higher. These earthquakes were applied as internal loadings to the incompressible, non-rotating, self-gravitating, Maxwell viscoelastic sphere representing the Earth. The displacements on the Earth's surface were calculated by solving the equations governing infinitesimal, quasi-static perturbations in the sphere by use of a Normal Mode Analysis.
The earth model is laterally homogeneous, adopting a crustal thickness of 40 km. The elastic crust is situated on top of a viscoelastic lithospheric mantle, which forms the uppermost part of the viscoelastic mantle. The lithospheric mantle is divided into an upper and lower part. The upper part, with a thickness of either 20 or 40 km, is effectively elastic on times scales of a few tens of years. The lower part has viscosities varied between 10^{17} and 10^{19} Pa s and a thickness such that the total thickness of the lithospheric mantle is 100 km.

The post-seismic model solutions show that in the Transylvanian Basin the velocities of the post-seismic deformation are very small, implying that it is likely that other geodynamic processes than post-seismic deformation are responsible for the horizontal displacements derived from the GPS observations in this region.
The interpretation of the results is more complicated for the Vrancea region toward the Black Sea and the Moesian platform. Although there is a very good fit for most of the vectors, both in direction and magnitude, this fit depends on the existence of a large sub-crustal low-viscosity zone for this region. If such a zone would be absent, then also here post-seismic deformation would be negligible and the observed plate motions of a few mm/yr should originate from other geodynamical processes. If an extensive low-viscosity zone would be present, then it might imply that present-day horizontal motions in this zone of former plate convergence would have reduced to almost insignificant values compared to the 3-4 mm/yr horizontal convergence of the past 4-5 Myr based on geological observations. The consequence might then be that the cause for frequent hazardous earthquakes in the region and the strong ongoing deformation of the Vrancea slab should be sought below the upper crust.